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(54) **Rotary liquid atomizer**

(57) A rotary liquid atomizer comprises a drive shaft (3) carrying for rotation therewith a rotary member (1) e.g. circlar tray-like or saucer-like in shape, having a symmetical upper liquid guide surface (11) and a peripheral annular rim (8) of which the inner wall inclines gradually radially outwards and upwards from the guide surface (11) terminating in a top wall (12) orientated perpendicular to the rotational axis. A large number of shallow grooves (13) are located around the rim (8) at substantially uniform small circumferential pitch, each extending between the periphery of the guide surface (11) and the top wall (12) in the direction of flow of liquid supplied to a central portion (6) of the rotary member (1) and caused to flow outwardly over the guide surface (11) by centrifugal force on rotation of the rotary member (1). Thus liquid flows outwardly through the grooves (13) in fine streams of substantially uniform diameter and issues therefrom at the top wall (12) as finely atomized substantially uniform droplets.

FIG. 1

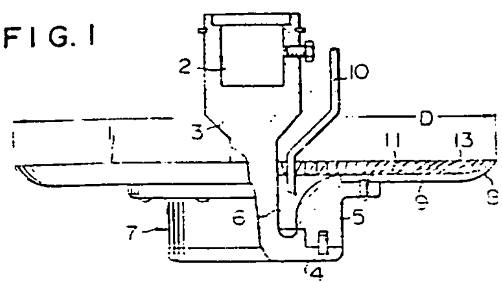

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FIG. 1

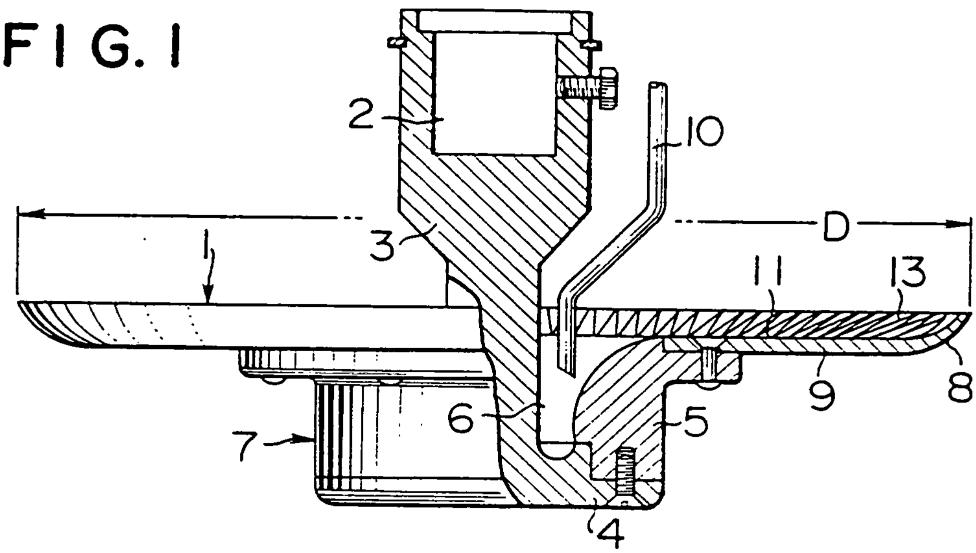


FIG. 2

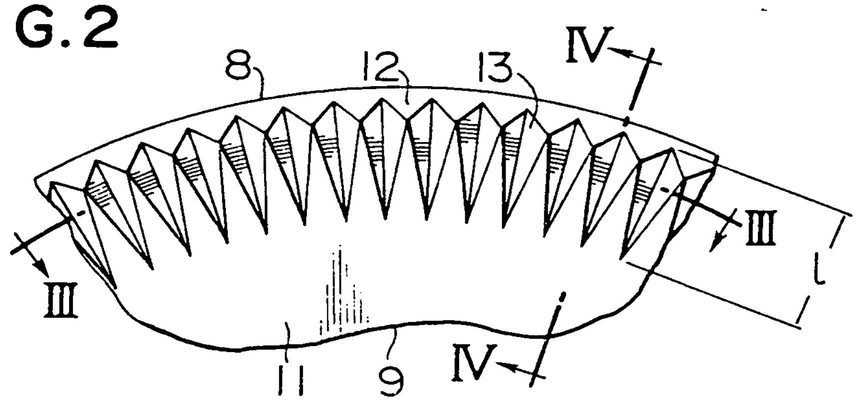


FIG. 3

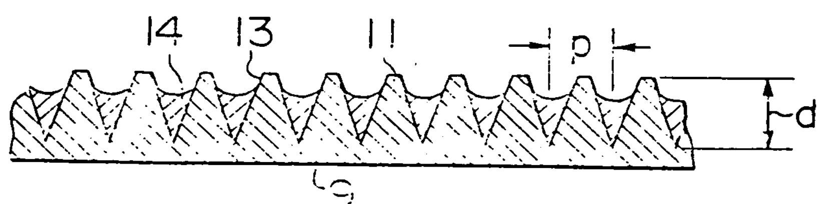
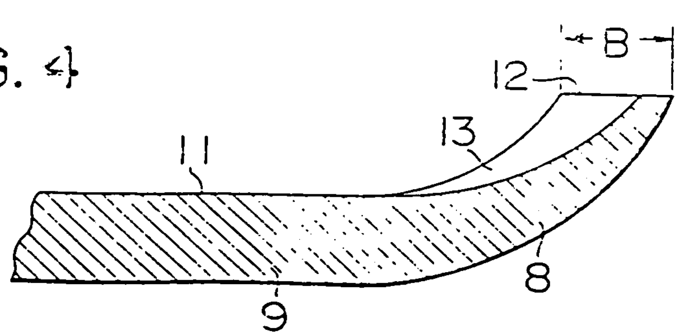


FIG. 4



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SPECIFICATION

Rotary liquid atomizer

This invention relates to a rotary liquid atomizer and more particularly to that type of rotary liquid atomizer wherein liquid is supplied continuously to a central portion or the inner portion distant from the peripheral edge of one side surface of a rotary member in disc form or bell form which is mounted coaxially with a driving shaft which is to be rotated at a high speed, and wherein liquid is guided to the peripheral edge of the rotary member along the side surface of the rotary member and is discharged from the periphery into the atmosphere by centrifugal force caused by the high speed rotation of the rotary member, whereby the liquid is atomized into fine particles.

Conventionally, in a rotary atomizer of the kind described above, the liquid supplied to one side of the rotary member is caused to flow along the surface of the rotary member towards its periphery in the form of a continuous thin film when the surface tension of the liquid is low. On the other hand, when the surface tension of the liquid is relatively high, the liquid moves so as to form a plurality of narrow streams which are separated from each other.

In the conventional rotary liquid atomizer, the liquid, having reached the periphery of the rotary member, extends outwardly beyond the periphery in the form of a thin film into the atmosphere maintaining the state when it flows. The liquid is then divided into sections, atomized and discharged by the centrifugal force which acts on the liquid rotating at high speed together with the rotary member, the force of friction with the surrounding air and the said surface tension of the liquid. In other words, the outer edge of the thin liquid film extending outwardly beyond the periphery of the rotary member is torn into plurality of streams of various sizes from which liquid droplets are formed directly or by entraining the air to form liquid droplets with bubbles. The end portion of each stream extending radially outward of the periphery of the rotary member has the form of a liquid strand having a relatively large diameter which is separated gradually into major droplets which are relatively large in size or into satellite droplets which are relatively small in size. Accordingly, the liquid droplets formed have a large mean diameter with a wide range of droplet size distribution and include many droplets with bubbles, whereas ideally the atomized droplets formed have a small diameter as the mean droplet size and a narrow range of droplet size distribution without entraining air.

For these reasons, the conventional liquid atomizer of the type described above is not suitable for use in, for example, atomizing liquid paint for the purpose of spray coating.

According to the present invention, there is provided a rotary liquid atomizer comprising
a drive shaft; and
a rotary member carried by the drive shaft for rotation therewith about the axis of the drive shaft, the rotary member having an upper surface which constitutes a liquid guide surface which surrounds said axis and of which at least a peripheral portion is substantially flat, and a peripheral annular rim which projects upwardly and which has a gently inclined wall which is joined to the periphery of the liquid guide surface and inclines gradually radially upwardly and outwardly therefrom to terminate in a top wall of the rim lying in a plane which is perpendicular to said axis, there being a plurality of shallow grooves formed in the gently inclined wall of the rim and extending between the periphery of the liquid guide surface and said top wall of the rim substantially in the direction of flow of liquid supplied to a central portion of the liquid guide surface, or a portion of the rotary member adjacent said liquid guide surface and spaced radially inwardly of the peripheral portion of said liquid guide surface, and caused to flow outwardly over said liquid guide surface by centrifugal force due to rotation of said rotary member about said axis, the grooves being located around the entire peripheral annular rim at a substantially uniform small circumferential pitch, whereby said liquid can flow into the shallow grooves and issue therefrom at said top wall of the rim.

In a rotary liquid atomizer according to the invention, the liquid supplied to the central portion of the liquid guide surface or a portion of the rotary member (e.g. a depression) which is spaced inwardly from the periphery of the member, is caused to flow radially outwardly along the guide surface as a continuous thin liquid film or as a number of fine streams, depending on the surface tension of the liquid, by the centrifugal force applied to the liquid due to rotation of the member. The liquid is thus guided to the peripheral edge portion of the guide surface to the inclined wall of the rim. Since the centrifugal force F applied to the liquid is represented by $F = m\omega^2r$, where m, ω and r represent, respectively, the mass of the liquid, the angular velocity of the rotary member and the radial distance from the centre of the same, and since the radial distance r increases as the liquid approaches the periphery of the rotary member, the centrifugal force acting on the liquid attains substantially its maximum value when the liquid reaches the peripheral edge portion of the inner guide surface of the rotary member where it is then forced to flow into the large number of fine shallow grooves by the centrifugal force, whether the surface tension is large or small, and is accordingly separated into a multiplicity of independent fine streams. These fine streams are then directed radially outwardly along their respective grooves being urged at the same time towards the bottom of the grooves. Thereafter the fine streams issue from the outer ends of the grooves which open on the top surface of the annular rim or projection as strands or cusps having substantially uniform small diameters. The strands can then be successively torn from the ends of the grooves and discharged into the atmosphere as fine liquid droplets.

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The present invention thus makes it possible to achieve atomized droplets having a relatively small mean droplet size and a narrow range of droplet size distribution, whether the surface tension of the liquid is small so that the liquid flows toward the peripheral edge portion of the inner surface as a thin liquid film under the influence of centrifugal force induced by the high rotational speed, or whether the surface tension is relatively large so that the liquid flows as a multiplicity of fine liquid streams along the inner surface of the rotary member toward the peripheral edge portion.

In other words, the smaller the diameter ϕ of the liquid streams issuing from the outer ends of the grooves, the better the atomization of uniform droplets.

The diameter ϕ of the liquid strands can be represented by the following equation:

$$\phi = C\sqrt{[V/(r \times GN \times N)]}$$

where

ϕ = diameter of liquid strand (cm)

C = constant which is substantially equal to 2

r = distance between the centre of the rotary member and the outer end of the grooves (cm)

GN = number of grooves

N = rotary speed of the rotary member per minute (r.p.m.)

V = rate of liquid supply (cc/min)

Thus, the larger the number of grooves provided at the peripheral edge portion of the inner surface of the rotary member sufficiently large the better the atomization. The radius of the rotary member, i.e. the distance from the centre of the rotary member to the outer end of the grooves, is suitably determined in accordance with the mean value of the rate of supply of the liquid which varies within a predetermined range. In addition, the number of revolutions of the rotary member is preferably increased or decreased in direct proportion to the rate of the liquid supply.

Reference is now made to the accompanying drawings which illustrate by way of example an embodiment of the invention and of which:

Figure 1 is a partially sectioned schematic front elevational view of a rotary liquid atomizer embodying the present invention;

Figure 2 is a plan view of a part of the rotary member incorporated in the rotary liquid atomizer shown in Figure 1;

Figure 3 is an enlarged vertical sectional view of the atomizer shown in Figures 1 and 2, taken along the line III–III of Figure 2 and as viewed in the direction of the arrows; and

Figure 4 is an enlarged vertical sectional view of the atomizer shown in Figures 1 and 2, taken along the line IV–IV of Figure 2 and as viewed in the direction of the arrows.

In the drawings, a rotary liquid atomizer includes a circular tray-like rotary member 1, comprising a circular collar-like metal plate 9 which is coaxially mounted on a metallic hub member 7. The metallic hub member 7 includes a short flared pipe 5 of which the inner surface has an upper portion extending radially outwardly. A rotary shaft 3 extends coaxially through pipe 5, having at its lower end a cover portion 4 which is secured over the lower end of pipe 5 as illustrated, to leave an annular space 6 in pipe 5 surrounding the shaft 3 and having a closed lower end. The rotary shaft 3 has a boss portion 2 at its upper end which is adapted for connection to the end portion of the driving shaft of an appropriate driving means, e.g. an electric or pneumatic motor, so that the rotary member 1 can be rotated, with the rotary member 1 symmetrical about the axis of rotation.

The circular collar-like metal plate 9, as clearly shown in Figure 4, has an inner portion having a flat upper surface 11, and a peripheral edge portion 8 which is curved so that it slopes gently upwardly and outwardly, away from the flat inner upper surface 11 to form an upstanding annular projection or rim 8.

The liquid to be atomized is supplied to the annular space 6 to form a liquid pool therein from a suitable liquid source (not shown) through a liquid supply tube 10, and is made to flow, due to centrifugal force caused by high speed rotation of the rotary member 1, substantially radially and uniformly along the upper surface 11 of the circular metal plate 9 towards the peripheral edge portion of the rotary member i.e. toward the annular projection or rim 8. The flow of liquid over surface 11 is either in the form of a continuous thin film or of a plurality of separated slender streams, depending on the surface tension of the liquid.

As shown in Figure 4, the annular projection or rim 8 is provided with a top surface 12 which is in a plane substantially perpendicular to the axis of rotation of the rotary member 1. At the periphery portion of the flat upper surface 11 of the circular metal plate 9, there are formed a large number of shallow grooves 13 which are V-shaped in cross section (Figure 3). The grooves 13 extend substantially in the direction of flow of the liquid, i.e. in the radial direction of the rotary member 1, and are disposed at a constant small circular pitch uniformly over the entire periphery of the rotary member 1, so that their outer ends open in the top surface 12 of the annular projection or rim 8.

In the illustrated embodiment, each of the grooves 13 has a planar shape of an elongated V (defined as the shape (when viewed as in Figure 2 in a direction parallel to the axis of rotation of the member 1), the width of each elongated V shape increasing towards its outer end, as shown in Figure 2, as well as a generally triangular (i.e. V-shaped) cross-section as shown in Figure 3. The depth of each groove gradually increases as it approaches its outer end (Figure 4). However, this particular planar shape (as defined herein), cross-section and depth of the groove are not essential.

For instance, if desired, the groove can have various planar shapes such as an elongated U, elongated

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trapezoid, an elongated V or U having a centre line which is gently curved into an arc and so forth. At the same time, the groove can have a cross-section which is triangular or trapezoid with a rounded bottom, triangular or trapezoid with rounded upper edges of both side walls and so on. At the same time, the groove can have a constant depth over its entire length.

It has been discovered that good atomization can be achieved using a rotary liquid atomizer of the construction described with reference to the drawings of which the dimensions and other parameters are as follows:

Diameter D of rotary member 1 = 30 mm to 1000 mm
Breadth B of top surface 12 of projection or rim 8 = 0.1 mm to 4.0 mm
Length l of each groove 13 = 1.0 mm to 15.0 mm
Depth d of each groove 13 = 0.05 mm to 3.0 mm
Pitch p of grooves 13 = 0.2 mm to 3.0 mm
Speed of rotation N of rotary member 1 = 300 r.p.m. to 40,000 r.p.m.

Thus, the speed of rotation N of the rotary member 1 can be varied over quite a wide range. However, as stated before, the diameter of the liquid strands extending outwardly from the ends of the grooves into the atmosphere must be small enough, to form liquid particles which are uniformly small in average diameter. The diameter of the liquid strands depends largely on the rate of flow in the grooves. Thereafter, the diameter D of the rotary member should be suitably selected to take into account the nature of the liquid to be atomized, the predetermined range of fluctuation of the supply rate and other conditions.

At the same time, the speed of rotation of the rotary body should be suitably varied so as to obtain the condition under which the liquid is forced into each groove by centrifugal force, in accordance with the variation of the rate of the liquid supply, with the liquid flowing outwardly within the lower half of each groove without spilling from one groove to another near the outer end of each groove as shown in Figure 3 where the reference numeral 14 indicates a liquid stream within a groove 13.

A large number of the shallow grooves provided at the peripheral portion of the liquid guiding surface of the rotary member in the rotary liquid atomizer of the invention can be formed quite easily and at low cost, by a simple manufacturing method, for example, a use of a knurling tool.

A rotary liquid atomizer made according to the invention and proved by experiment to afford good atomization had the following dimensions:

D = 73.5 mm
GN = 664
l = 2.0 mm
d = 0.15 mm
p = 0.35 mm (measured at the peripheral edge portion of the liquid guiding surface 11).

A white amino-acrylic resin enamel of a viscosity of 25 sec/zahn cup #2 was supplied to the rotary member at a rate V of approximately 600 cc per minute. The behaviour in which the liquid strands were generated at the peripheral edge of the rotary member, when the member was rotated at a speed of N = 12,000 r.p.m., was recorded by means of strobo-photo, at a 4/1,000,000 second exposure. The liquid strand or cusp in the photo exhibited a diameter ϕ of about 90 microns, and it was confirmed that the end portions of the strands or cusps were continuously and successively separated into fine particles which were small in mean diameter and had a narrow range of particle size distribution and further were highly suitable for the spray coating of the resin enamel.

It will be seen from the foregoing description that, using a rotary liquid atomizer according to the invention, extremely fine and uniform atomized liquid particles can be obtained simply by the centrifugal force applied to the liquid due to high speed rotation of the rotary member. Accordingly, the greatest effect will be obtained in each case of the application in the atomization of liquid or paint for spray coating, the spray deseccation of slurry matters for powder or particle making, the atomization of liquid fuel for combustion apparatus and other general atomization.

Moreover it will be evident from the description that the rotary liquid atomizer of the member need not necessarily have a circular tray-type shape, but may alternatively be bell-shaped.

CLAIMS:

1. A rotary liquid atomizer comprising a drive shaft; and

a rotary member carried by the drive shaft for rotation therewith about the axis of the drive shaft, the rotary member having an upper surface which constitutes a liquid guide surface which surrounds said axis and of which at least a peripheral portion is substantially flat, and a peripheral annular rim which projects upwardly and which has a gently inclined wall which is joined to the periphery of the liquid guide surface and inclines gradually radially upwardly and outwardly therefrom to terminate in a top wall of the rim lying in a plane which is perpendicular to said axis, there being a plurality of shallow grooves formed in the gently inclined wall of the rim and extending beteween the periphery of the liquid guide surface and said top wall of the rim substantially in the direction of flow of liquid supplied to a central portion of the liquid guide surface, or a portion of the rotary member adjacent said liquid guide surface and spaced radially inwardly of the peripheral portion of said liquid guide surface, and caused to flow outwardly over said liquid guide surface by centrifugal force due to rotation of said rotary member about said axis, the grooves being located around the entire peripheral annular rim at a substantially uniform small circumferential pitch, whereby said liquid can flow into the shallow grooves and issue therefrom at said top wall of the rim.

2. A rotary liquid atomizer as claimed in claim 1, in which said rotary member is bell-shaped.

3. A rotary liquid atomizer as claimed in claim 1, in which the rotary member has the shape of a circular tray or saucer.

4. A rotary liquid atomizer as claimed in claim 1 or claim 3, in which an annular depression in the upper surface of said rotary member is provided about said drive shaft in which a pool of liquid can be formed and from which liquid can flow over the liquid guide surface upon rotation of said rotary member about said axis.

5. A rotary liquid atomizer as claimed in any of claims 1 to 4, in which each of the shallow grooves has an elongated V or U-shape when viewed in a direction parallel to the axis of rotation of the rotary member.

6. A rotary liquid atomizer as claimed in any of claims 1 to 5, in which each of the shallow grooves has a generally triangular cross-section.

7. A rotary liquid atomizer as claimed in any of claims 1 to 6, in which the depth of each of the shallow grooves increases in the direction from the periphery of the liquid guide surface to said top wall of the rim.

8. A rotary liquid atomizer substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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